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OPTIMIZING THE PLACEMENT OF GUIDANCE ARROWS ON HIGHWAY SIGNS

George Allen Emerson

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THESIS

OPTIMIZING THE PLACEMENT OF GUIDANCE
ARROWS ON HIGHWAY SIGNS

by

George Allen Emerson Jr.

September 1975

Thesis Advisor: D. E. Neil

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T169659

REPORT DOCUMENTATION PAGE

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1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER
4. TITLE (and Subtitle) OPTIMIZING THE PLACEMENT OF GUIDANCE ARROWS ON HIGHWAY SIGNS		5. TYPE OF REPORT & PERIOD COVERED Master's Thesis; September 1975
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s) George Allen Emerson Jr.		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Naval Postgraduate School Monterey, California 93940		12. REPORT DATE September 1975
		13. NUMBER OF PAGES 38
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office) Naval Postgraduate School Monterey, California 93940		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Traffic Control Devices
Guidance Signs

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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20. Abstract

possible. The measured variables were response time and correctness of the response. Classical statistical tests were used to conduct the analyses. The analyses were made to determine the optimum guidance sign design regarding the arrangement of arrows and destination names.

Optimizing the Placement of Guidance Arrows
on Highway Signs

by

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Lieutenant, United States Navy
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Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN OPERATIONS RESEARCH

from the

NAVAL POSTGRADUATE SCHOOL
September 1975

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ABSTRACT

This paper describes a design and experimental study of the placement of guidance arrows on highway guide signs. This study was conducted under laboratory conditions. Ten subjects were shown a series of slides depicting three destinations, three directions and three sign designs under controlled instruction and exposure duration; they were required to respond to a previously determined cue as quickly and as accurately as possible. The measured variables were response time and correctness of the response. Classical statistical tests were used to conduct the analyses. The analyses were made to determine the optimum guidance sign design regarding the arrangement of arrows and destination names.

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I. INTRODUCTION

A. PROBLEM DEFINITION

1. Driving Statistics

The automobile has become an integral part of the American life style as evidenced by the pollution, smog, traffic jams and ribbons of highways crisscrossing the country. Most likely the automobile will never cease having an impact on the people of our country, even when they are threatened with an energy crisis. One would be fairly safe in saying that automobiles and highways are here to stay, at least for the forseeable future.

With the automobile and highway systems playing such a large part in this country's way of life, traffic accidents and deaths will probably continue to plague the population. The Directorate of Aero Space Safety [1970] stated that statistically during a lifetime one out of every two United States citizens has been or will be disabled or killed in a traffic accident. In 1973 murderers killed 19,000 Americans, however traffic accidents killed 55,800 persons. Criminals inflicted about 500,000 injuries on Americans; traffic accidents caused 2,000,000 injuries. The direct cost of "serious crime" cost five billion dollars; traffic accidents exceeded 20 billion dollars annually [Double Clutch 1975]. The transportation problem and the traffic control problem within the United States has reached

acute proportions as indicated in the figures above. However one does not have to go any farther than his daily newspaper to gather these gruesome facts. Unfortunately Department of Defense personnel are included in this group of statistics. The Air Force averaged 381 deaths per year in the years 1965 to 1969 with an annual average of 4,363 accidents [Directorate of Aero Space Safety 1970].

One aspect of the transportation system involving automobiles and the driver are the signs placed along roads and highways. These signs represent a source of information which enables the automobile operator to drive safely and correctly on these transportation arteries. Sheridan [1974] refers to data or other evidence as the property of messages that reduces one's uncertainty about the true state of affairs. This is what a traffic sign attempts to do, reduce one's uncertainty about the driving task.

2. The Driving Task

Before continuing, it would be prudent to explain the driving task so one will better understand how signs are related to the task. Driving is a task which can be broken up into three sub-tasks: control, guidance and navigation [Alexander et al 1972]. Control relates to the driver's interaction with the automobile and does not require the use of highway signs to be successfully accomplished. Guidance refers to the driver's ability to maintain a safe path on the highway; regulatory and warning signs assist the driver with this sub-task. Finally, navigation which refers to the drivers ability to plan and execute a trip from a point of origin to a destination requires the use of guide signs to provide information to the driver in order for him to properly carry out this sub-task. Therefore, it is evident that signs play an important part in the task called

driving, and without the benefit of signs, it would be severly restricted or perhaps even impossible to accomplish, given the present complex highway system.

B. INFORMATION GATHERING

1. Getting Information to the Driver

Although the driver obtains information via all his senses, the information-gathering discussion is structured in terms of the driver's visual reception. The primary source of information by the driver is the eye, which accounts for 95 percent of all his input information [Schmidt et al 1966]. The information needs of the driver can be categorized in accordance with his information inputs. The relevant input category deals with directional performance and consists of two distinct phases: (1) trip preparation and planning which is usually a pretrip activity, and (2) direction finding which occurs while in transit. During the direction finding phase the driver on the road must find his destination in the highway system in accordance with his trip plan and the directional information received in transit. It must be remembered that he will always be performing other tasks requiring information processing. The driver has a priori knowledge which he brings into the driving task and he obtains and uses information in transit.

2. Information Sources and the Driver

King [1971] has suggested that a driver can attend to only one information source at a time. Task analysis of the driving operation has shown that there is considerable task-sharing throughout the driving operation. Furthermore, it has been shown that diverse information sources compete for the driver's attention, especially in high-signed areas such as at interchanges and in the urban areas. The situation is further complicated on high-speed interstate routes where the driver is faced with time pressures as well as competing information needs and task sharing. The driver's ability to perform well in high-signal, high-speed situations then depends on his ability to time-share his attention among the competing information sources, and focus his attention on the most important information needs. His ability to perform is obviously based on the nature of the decisions that he must make.

3. Driving Skills

Cumming [1964] stated that one of the most important driving skills is the skill of systematically and efficiently gathering information. He cites studies of filmed records of drivers' eye movements, which indicate a maximum rate of sampling from separate information sources of about one to 1.4 per second. He concludes that this slow rate is not sufficient to give the driver enough of the information that he needs. Cumming has concluded that the driver relies on his short-term memory and his ability to integrate information; he also fills information gaps with expectancies. Thus, his scanning technique under time pressure is a function of his driving experience. It has

been suggested by Schlesinger [1963] that the ability of the driver to observe the environment efficiently is so critical to the driving task that he should be taught sequential scanning routines as a part of driver education. While operating a vehicle on the road the operator is faced with the problem of maintaining an appreciation of a dynamic environment in which he must continuously predict what will occur in the next instant. In addition to predicting he must integrate the information he receives to maintain this dynamic appreciation. Because the driver is an important link in the transportation system, one should look closely at the ability of how he performs within the system. The purpose of a highway system is the safe, comfortable, convenient and efficient movement of goods and people and a lost driver is a system failure. As the information challenge increases, a point is reached where the driver is unable to handle and process the amount of information required to resolve the uncertainty of the decision. It is at this point that the driver's channel capacity is said to be exceeded [King 1971].

4. Channel Capacity

An important point concerning channel capacity of the driver is that if the information challenge becomes very great the "confusion effect" sets in so that not only is the driver unable to process the heavy information challenge, but he also seems to show a marked decline in the amount of information that he can transmit error-free,i.e. his channel capacity is decreased [Quastler 1956].

Although channel capacity is a fixed value for a particular individual at a particular time, it is possible to increase an individual's apparent channel capacity by recoding, or organizing bits of information into chunks

[Miller 1956]. Channel capacity is the limiting factor for the amount of information processed in any time period, however, the immediate memory, which is apparently independent of channel capacity, is the limiting factor for recoding information [King 1971]. The principle of recoding states that if a complex code can be taught to drivers, elements of this code can be presented in lieu of the original information. An important limiting factor in recoding is that the driver must know the code.

C. HIGHWAY SIGNS: A MEANS FOR MANEUVERING

1. Communicating with the Driver

The signs used on the roadways of the United States are a collection of shapes, colors, symbols, pictures and words, combined so as to provide maximum information to the driver. Researchers' knowledge of information theory and human performance has lead to the development of better, more informative signs which convey information to the driver not only by the printed message, but also by the shape, color and symbol on the sign. Most people are quite familiar with the standard STOP sign seen at many intersections. In addition to the word "STOP", the sign has the redundant features of the octogonal shape and the red color to reinforce the meaning of the word "STOP". The Russians, in their search for a better stop sign, tried the American version, found that it worked, and are using it on highways throughout the Soviet Union ["Symbol Signs Show the Way" 1975]. Other signs have similar redundancy built in, to aid the driver in his information processing task.

Navigational signs use letters, numbers and

pictographs to convey information. Sheridan [1974] has stated that physical systems used as information channels are limited both in the amount and the rate of bits of information transmitted; therefore, it should not be suprising to find the driver having similar limitations. A driver can only process a limited amount of information under a given set of circumstances before he will either make an error or miss information needed to perform properly. When the driver cannot process all the necessary information there can be either a catastrophic failure of the system (an accident), or a non-catastrophic failure (a driver missing his turn-off from the highway or a driver who becomes lost) [Alexander et al 1972]. In a study conducted by the Department of Transportation, four out of five automobile accidents were attributed to human error [Accident Causes 1975]. The four leading human errors were improper lookout, excessive speed, inattention and improper evasive action. Also cited were the leading environmental factors: view obstruction, slick roads and roadway design problems. It then would seem likely that if one could remove more uncertainty from the drivers task, the probability of an accident would be lowered in both human error cases and environmental factor cases.

If a person stands along the side of a highway and looks at a navigational sign, he probably can read the sign quite easily. If a sign is legible, will it accomplish its goal of transmitting the proper information to the driver of a motor vehicle? Not necessarily. One must enter the environment of the driver to better understand this problem.

2. Early Sign Systems

Since the very early days of highway signing systems, guidance signs in the United States were handled

under very general guidelines. Various local and state agencies were left to their own devices insofar as basic sign design was concerned. As highway speeds increased the signing systems have become more specific and rigorous concerning regulatory and warning signs. Guide signs, however, have not followed suit in terms of standardization with the exception of the route markings. Problems with United States guide signs lie in content and design of the signs. Markowitz [1968] has stated that without a comprehensive point of view, U. S. guide signs have proliferated without adding to the effectiveness of the system.

Signing authorities have agreed that no more than three (or four) destination names should appear on the same guide sign. When too many names appear on a guide sign, it is confusing, too hard to read and too lengthy to read in the short periods of time allowed for safe navigation of today's highways.

3. <u>Sign Attributes</u>

The attributes of the sign which contribute to the optimization of legibility and detectability are the physical components of sign design, while the attributes that contribute to the optimization of comprehension are inherent in the message. Comprehension is a consequence of the sign's function as an information source; legibility and detectability are consequences of its function as a transmitter of information. The degree of noise present at the transmitter, channel or receiver affects all three elements [King 1971].

D. SIGN READING STRATEGIES

Markowitz [1968] has stated that everyone does not read a sign, at least everyone does not read a sign in the same way. People have different goals or reasons for driving on the highway and these goals lead to different strategies of driving of which two are of interest and will be designated "search" and "discovery" respectively.

The "search" technique refers to the situation where an observer, approaching a choice point, has a well defined destination in mind and fully expects to find this name on the sign. The observer's job is to search through the names on the guide sign until he locates the one for which he is searching and then finds the direction associated with it.

The "discovery" technique applies when an observer either has no well defined destination or does not expect to find his destination on the sign. This observer must "discover" which destination names go with which directions; having discovered the named destination most properly related to his destination, the observer will then know in which direction to proceed.

Markowitz [1968] indicates there is not sufficient information available for one to make a decision on whether to stress one strategy over the other. He suggests possibly a compromise in providing the drivers with primary and secondary information on separate signs.

E. OBJECTIVE OF THIS EXPERIMENT

The overall objective of this study was to ascertain an optimum position for guidance arrows in relation to destination name on highway guide signs. The original hypothesis would be that the staggered arrangement is more conducive to the needs of the driver using either the "search" or "discovery" strategy.

II. METHODS

A. SUBJECTS

There were ten subjects who observed all combinations of six experimental factors. Five subjects were male students at the Naval Postgraduate School and five subjects were females, wives of students at the Naval Postgraduate School. Their ages ranged from 26 to 39 years. The average ages were 31 years for the males and 27.6 years for the females. Nine of the ten subjects had some type of formal Driver's Education course early in their driving career and all subjects have been driving for at least ten years. All subjects' visual acuity except one was either 20/20 or corrected to 20/20; the exception was corrected to 20/40. The subjects were not compensated for their time.

B. EQUIPMENT

The experimental equipment used in conducting this experiment consisted of a Lafayette Instrument Company Number 12910 Random Access Control and Optional Reader and a VS-1E All-Purpose Electric Tachistoscopic Attachment mounted in a KODAK EKTAGRAPHIC (RA960) Projector. A previously randomized set of tapes was used on the paper tape reader in order to access a slide on the projector. The tachistoscope was triggered electronically by the timer in the control loop; the solenoid shutter was also controlled by the timer.

The exposure durations were 100 and 200 milliseconds. The system was set up to operate in a continuous loop with a mean time between slides of six seconds.

The subject responded to the stimuli by depressing one of three choice buttons which when pushed indicated his response by lighting a light on the response panel. His response also stopped the timer which indicated his response time.

The subjects were placed in an environmental enclosure to remove as many external distractions as possible.

C. STIMULI

The stimuli used in this series of experiments consisted of a set of white-on-green guide signs containing three destination names - Salinas, Sacramento and Seaside. The guide signs were placed on slides for controlled presentation to the subjects.

Each of the destination names could occur in any one of the three positions on the sign (top, middle or bottom) and be associated with any one of the three directions of travel (right, left or straight-ahead). Representative selections of the signs are reproduced in Fig. 1 below. There were no duplications of direction on any one slide. The arrows representing the direction of travel could be in one of three arrangements: (1) all direction arrows to the left of the destination names, (2) all direction arrows to the right of the destination names or (3) staggered with the top and bottom arrows to the left of the destination names and the middle arrow to the right. All possible combinations of these variables were used.

Figure 1 - SOME SPECIMEN GUIDE SIGNS USED IN EXPERIMENT.

D. PROCEDURES

The experiment was conducted in the Man-Machine System Design Laboratory at the Naval Postgraduate School, Monterey, California. All subjects were tested three times over a period of a week; the first two meetings were familiarization sessions. Each session lasted 75 minutes, during which time a subject was exposed to a random selection of the stimuli presented tachistoscopically.

Each session was divided into five parts. The first part was a practice or warm-up period, where the subject responded by naming the destination associated with a designated position on the sign. The remaining four parts were based on factors Instruction and Exposure. Each part consisted of nine blocks of ten trials.

The "search" and "discovery" criterion were permuted with the exposure time of 100 ms and 200 ms. The four combinations were then chosen randomly for each Subject for each session. If the "search" criterion was tested, the subjects were required to give the direction of travel associated with a particular destination name. If the "discovery" criterion was tested, the subjects were required to give the destination associated with a particular direction. The particular name or direction was changed for each block. The first trial of each block was considered a prepatory stimulus. As such, it was not considered comparable to the test trials and was excluded from the analysis.

Between each part, the subject was allowed to rest for two minutes and the subjects were encouraged to exercise and rest their eyes in between blocks.

E. DESIGN

Data from the present experiment was analyzed according to a seven-way factorial analysis of variance (ANOVA) with subjects performing all factorial combinations. All factors except Subject had fixed levels assigned. Table I shows the seven main factors and the number of levels of each factor.

Main Factor	Level
Subjects (S)	10
Name (N)	3
Position (P)	3
Direction (D)	3
Arrow Arrangement (A)	3
Instruction (I)	2
Exposure (E)	2

TABLE I: Main Factors and Levels of Individual Factors.

Two dependent variables were used for the experiment: response time and frequency of correct response. Response time was measured from the exposure of the stimulus until the subject depressed the response button; these times were measured in hundredths of a second with a tolerance of five percent.

III. RESULTS AND DISCUSSION

The results will be examined in two parts. First the response time as used as a measure of performance will be presented; second the frequency of correct response as used as a measure will be presented.

A. RESPONSE TIME: A MEASURE OF PERFORMANCE

The response time for each individual trial was used as the measure of performance. The data was subjected to an analysis of variance with subjects receiving all treatment combinations. The criterion for accepting a value as significant was set at 0.05.

The main effects of Subject, Name, Position, Arrow Arrangement and Instruction were found to be significant. These results from the ANOVA are provided in summary form in Table II below. Complete results of the analysis of variance are in Appendix A.

Source	df	F
Subject	9,2720	101.29
Name	2,18	26.39
Position	2,18	15.25
Arrow Arrangement	2,18	14.88
Instruction	1,9	46.10
N X D	4,36	8.00
N X A	4,36	2.71

TABLE II: Summary of Significant Results at a Level $p < 0.05$.

The Newman-Keuls range test [Hicks 1973] was used to test for significance at the 0.01 level for the main effects. These results are summarized in Table III.

Subjects	Mean Response Time (MRT)
1	0.87
2	1.12
3	1.17
4	1.01
5	1.34
6	0.93
7	1.29
8	1.02
9	1.051
10	1.054

Name	MRT	Results
1 Sacramento	1.01	Sacramento is significantly more discernible than Seaside or Salinas ($p < 0.01$).
2 Salinas	1.12	
3 Seaside	1.12	

Position	MRT	Results
1 Top	1.14	The Middle Position is more discernible than either the Top or Bottom Position ($p < 0.01$).
2 Middle	0.98	
3 Bottom	1.14	

Direction	MRT	Results
1 Right	1.10	The main effect was not significant.
2 Left	1.09	
3 Straight	1.07	

Arrow Arrangement	MRT	Results
1 Right	1.12	There was no significant difference in means ($p < 0.05$).
2 Left	1.06	
3 Staggered	1.07	

Instruction	MRT	Results
1 Search	0.96	Means are significantly different ($p < 0.01$).
2 Discovery	1.21	

Exposure	MRT	Results
1 100 ms	1.09	The main effect was not significant.
2 200 ms	1.04	

TABLE III: Mean Response Times and Results of Range Tests.

There was a significant difference in mean response time for Subjects. This significant effect indicated that subjects took longer to respond and their response time was a function of the manner in which they perceived the weighting of speed versus accuracy as well as inherent subject differences.

The significant effect of Name indicated that Sacramento was more discernible over either Salinas or Seaside. This possibly could be explained by the difference in name lengths.

The Position effect showed that there was a significant difference in the middle position over the top and bottom positions. This observation could be explained by the experimental set-up of short exposure duration requiring the subjects to focus their eyes at the expected center of the slide and expand their visual field to encompass the whole slide or it could also be explained as subjects seeking an optimal search technique.

The Arrow Arrangement effect was significant as a group, however, the individual means were not significant.

The Instruction effect was significant and indicated that the "search" technique required less time to respond than the "discovery" technique.

Figures 2 and 3 show the significant interactions of Name X Direction (N X D) and Name X Arrow Arrangement (N X A). The figures indicated that Sacramento was more discernible than either Seaside or Salinas. Figure 2 indicates that either the Arrow Arrangement with the arrows on the Left or Staggered is superior to the design with the arrows on the right.

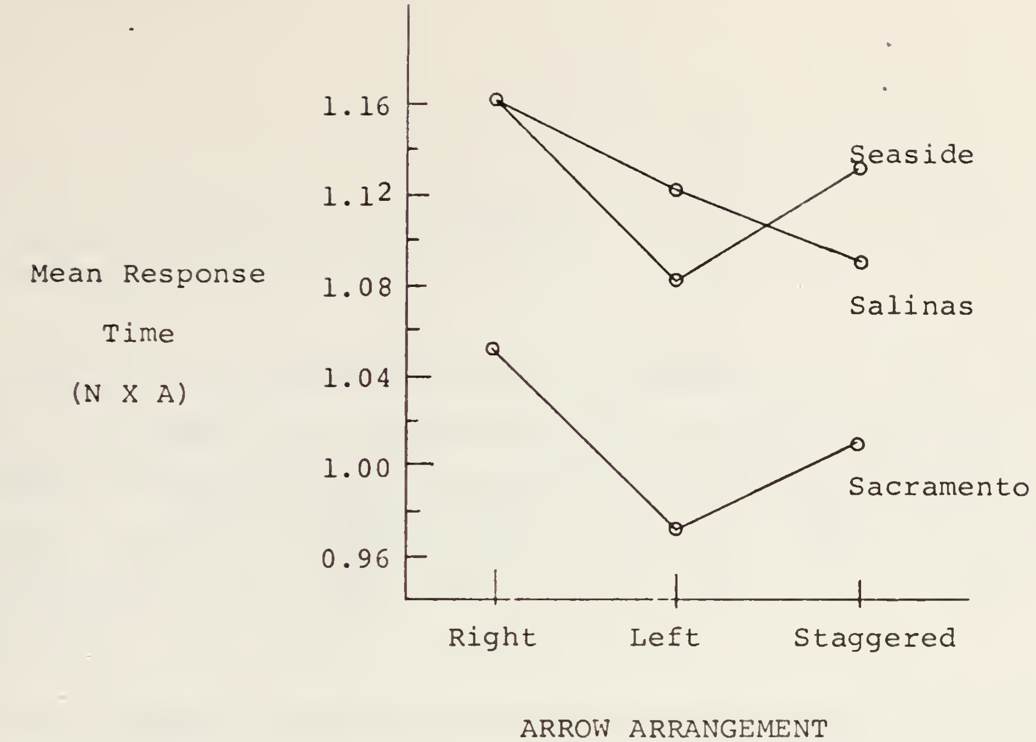

Figure 2 - GRAPH OF NAME X ARROW ARRANGEMENT

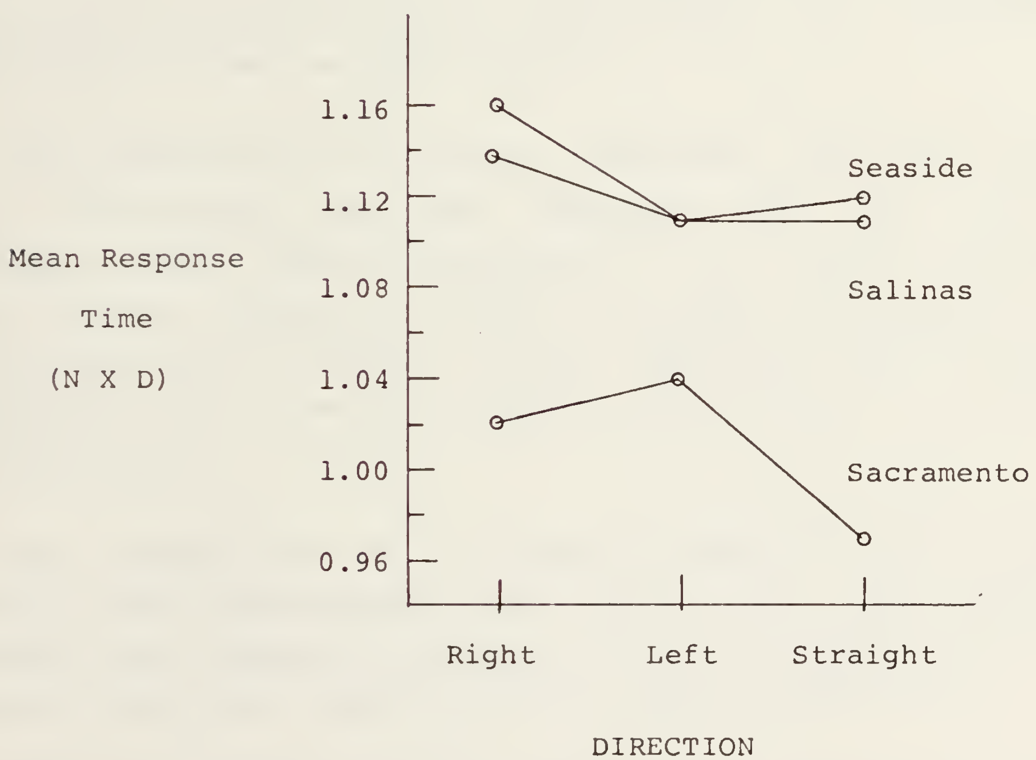

Figure 3 - GRAPH OF NAME X DIRECTION

B. FREQUENCY OF CORRECT RESPONSE

Using the frequency of correct responses for the total number of trials as a probability of a correct response, an analysis was conducted to determine any parallels in the two measures of effectiveness (MOE). Table IV shows the pooled probabilities for each main factor and its standard deviation.

The subjects' probabilities of correct response ranged from 0.781 to 0.932. Using the Spearman rank correlation coefficient to test the correlation of speed versus accuracy, the test resulted in a correlation of 0.188, indicating no attributable relationships in subjects' strategies of speed versus accuracy.

The probability of a correct response for the factor Name paralleled the mean response time MOE in that Sacramento had a higher probability of a correct response than either Salinas or Seaside. The same was true for the factor Position in that the Middle Position had a higher probability of a correct response over either of the other two positions.

The probability of a correct response for the factor Direction was approximately the same for all three levels, however the probability of a correct response for going Straight-Ahead was slightly higher than the other two.

For the factor Arrow Arrangement the probability of a correct response was much more likely for the Left or Staggered design than the Right design which was also true of the mean response time MOE. In this test the Staggered

design allowed a much better performance for seven of the ten subjects; one subject missed an equal number in each of the two categories and the other two favored the Left design just slightly in that they had fewer misses for the Left design.

The probability of a correct response for the factor Instruction also paralleled the mean response time MOE in that Search had a much higher probability of a correct response than Discovery.

C. SEX DIFFERENCES

There were no differences in mean response time or in frequency of correct response between males and females as a group.

SUBJECTS

	Mean	S.D.
S1	0.904	0.016
S2	0.827	0.021
S3	0.932	0.014
S4	0.886	0.018
S5	0.781	0.023
S6	0.802	0.022
S7	0.815	0.022
S8	0.852	0.020
S9	0.917	0.015
S10	0.910	0.016

NAME

Sacramento		Salinas		Seaside	
Mean	S.D.	Mean	S.D.	Mean	S.D.
0.923	0.008	0.827	0.012	0.840	0.011

POSITION

Top		Middle		Bottom	
Mean	S.D.	Mean	S.D.	Mean	S.D.
0.813	0.012	0.920	0.008	0.856	0.011

DIRECTION

Right		Left		Straight	
Mean	S.D.	Mean	S.D.	Mean	S.D.
0.853	0.011	0.858	0.011	0.879	0.010

ARROW ARRANGEMENT

Right		Left		Staggered	
Mean	S.D.	Mean	S.D.	Mean	S.D.
0.795	0.012	0.881	0.010	0.913	0.009

INSTRUCTION

Search		Discovery	
Mean	S.D.	Mean	S.D.
0.912	0.007	0.814	0.010

EXPOSURE

100 ms		200 ms	
Mean	S.D.	Mean	S.D.
0.847	0.009	0.880	0.008

TABLE IV: Mean and Standard Deviation of the Probability of a Correct Response.

IV. SUMMARY AND CONCLUSION

The effects of the mean response times and the probabilities of a correct response will be discussed in terms of the independent variables. The results of this experiment will be compared with the results observed by Markowitz [1968].

A. NAME

The choice of appropriate destination names appeared to be an important consideration in conducting the experiment. When one chooses names for the destinations consideration must be paid to name length, first letter, novelty of the name and possibly lack of familiarity to the names in order that bias will not be introduced unknowingly. The choice of Sacramento appears to have violated these prior considerations. Subjects in describing how they cued themselves during the experiment admitted using the length of the word Sacramento as a cue. One of the subjects used a combination of word length and the fact that Sacramento ended in "o".

Comparing the mean response times or the probability of a correct response for Seaside and Salinas, one observes approximately equal discriminability between the two. However, Sacramento stands alone when measured against either MOE.

B. POSITION

In this experiment as well as the one conducted by Markowitz [1968] the Middle position was more discernible than the other two positions.

In investigating the effect of position on a sign during a brief exposure, one must remember that the experiment was conducted under laboratory conditions. Subjects were required to attend to only one task in conducting this experiment which does not conform to the normal driving task involving time-sharing between many tasks.

One should have reservation in concluding that the Middle position is "more readable" or that drivers use a strategy of reading the middle position first under actual conditions. This effect if deemed important in final design consideration should warrant further investigation.

C. DIRECTION

In analyzing the effect of direction the mean response times were not significant. The relative relationships for the three directions of mean response time and the probability of correct response supports Markowitz' [1968] findings. This indication might support a superior performance for the direction Straight-Ahead. Also because the set of direction arrows includes only one vertical arrow and two horizontal arrows, the vertical arrow being unique would increase the probability of superior performance in the direction Straight-Ahead [Markowitz 1968].

D. ARROW ARRANGEMENT

The Arrow Arrangement analysis is not conclusive. The design with the arrow placement on the right is inferior to either the design with the arrow placement on the left or staggered. This is the same conclusion drawn by Markowitz [1968]. However, one can not say that the staggered design is better than the design with the arrows to the left of the destination name; yet, Markowitz' [1968] d' MOE and the probability of a correct response favor the staggered design slightly.

E. INSTRUCTION

The two strategies, Search and Discovery, appear to show a marked difference in both the mean response time and the probability of a correct response. The Search strategy requires less time to process and has a higher probability for a correct response. This effect was not demonstrated in Markowitz' [1968] experiment, however, he conducted the two experiments separately running the Discovery series subsequent to the Search series. The "differences [that he observed] may merely reflect order effects;" his results showed that the Discovery strategy was "marginally superior" to that of the Search strategy.

The subjects that performed both strategies during the same experiment operated under similar conditions with the learning effect randomized over all trials; consequently all other effects being equal, subjects using the Search strategy performed better.

F. EXPOSURE

Increasing the exposure duration did not demonstrate a marked increase in performance. This would indicate that 100 ms duration or possibly less was adequate viewing time for this experiment. However, one must remember that the driving task is a multi-task job requiring time-sharing on the part of the driver. In order to evaluate the effect of exposure more fully a similar experiment should be conducted requiring subjects to time-share.

G. CONCLUSION

The overall goal of this experiment was to examine the hypothesis that the staggered design was the optimal design in regards to arrow placement. This fact was not demonstrated in a clear fashion. Further study of this problem will be required to resolve the ambiguities presented.

One consideration that would be worthy of study would be the effect of coding and redundancy of Position and Direction. One design would be to always use the Top position for the Straight-Ahead direction, the Middle position for the Right direction and the Bottom position for the Left direction. One could then instruct the subjects in this code and evaluate either the Left/Staggered design or all three designs.

APPENDIX A

ANOVA TABLE FOR MAIN EXPERIMENT

Source	df	SS	MS	F	p<
Subject	9	63.77	7.09	101.29	.001
Name	2	9.49	4.75	26.39	.001
Error (N * S)	18	3.22	0.18		
Position	2	19.21	9.61	15.25	.001
Error (P * S)	18	11.39	0.63		
Direction	2	0.74	0.37	1.95	ns
Error (D * S)	18	3.36	0.19		
Arrow Arrangement	2	2.38	1.19	14.88	.001
Error (A * S)	18	1.40	0.08		
Instruction	1	48.87	48.87	46.10	.001
Error (I * S)	9	9.55	1.06		
Exposure	1	0.26	0.26	0.55	ns
Error (E * S)	9	4.26	0.47		
N * P	4	0.24	0.06	1.2	ns
Error (N * P * S)	36	1.70	0.05		
N * D	4	0.94	0.24	8.0	.001
Error (N * D * S)	36	1.09	0.03		
N * A	4	0.74	0.19	2.71	.05
Error (N * A * S)	36	2.53	0.07		
N * I	2	0.14	0.07	0.5	ns
Error (N * I * S)	18	2.44	0.14		
N * E	2	0.14	0.07	1.4	ns
Error (N * E * S)	18	0.87	0.05		
P * D	4	0.23	0.06	0.75	ns
Error (P * D * S)	36	2.93	0.08		
P *A	4	0.57	0.14	2.0	ns
Error (P * A * S)	36	2.46	0.07		
P * I	2	0.08	0.04	0.44	ns
Error (P * I * S)	18	1.62	0.09		
P * E	2	0.25	0.13	1.86	ns
Error (P * E * S)	18	1.22	0.07		
D * A	4	0.78	0.20	2.00	ns
Error (D * A * S)	36	3.75	0.10		
D * I	2	0.03	0.02	0.22	ns
Error (D * I * S)	18	1.62	0.09		
D * E	2	0.01	0.01	0.17	ns
Error (D * E * S)	18	1.10	0.06		
A * I	2	0.25	0.13	0.48	ns
Error (A * I * S)	18	4.82	0.27		
A * E	2	0.04	0.02	0.10	ns
Error (A * E * S)	18	3.61	0.20		
I * E	1	0.00	0.00	0.00	ns
Error (I * E * S)	9	2.19	0.24		
RESIDUAL	2720	181.34	0.07		
TOTAL	3239	397.63			

ns: not significant

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